AD-A214 695

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1979	Final

4. TITLE AND SUBTITLE
INVERSE SCATTERING: IONOSPHERIC STRUCTURE DETERMINATION

5. FUNDING NUMBERS
61102F
2304/A4

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8. PERFORMING ORGANIZATION REPORT NUMBER
89-1413

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR
BLDG 410
BAFB DC 20332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFOSR 78-3608

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

14. SUBJECT TERMS	15. NUMBER OF PAGES
	9
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified		

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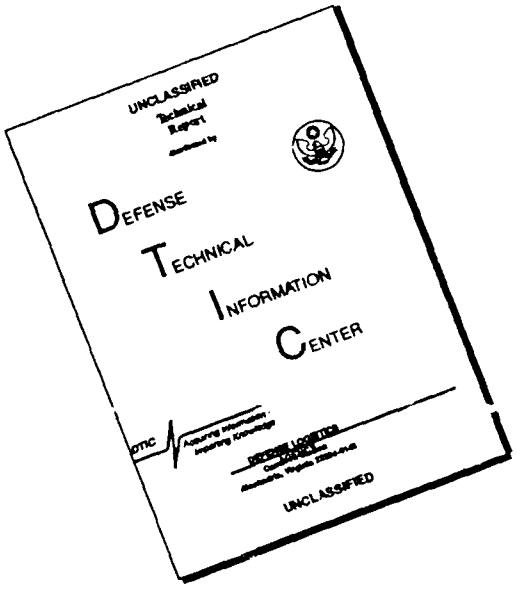

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AFOSR-78-3608

Inverse Scattering: Ionospheric Structure Determination

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July 1979
Final Technical Report
for period 1 July 1978 to 30 June 1979

Air Force Office of Scientific Research
Directorate of Mathematical and Information Sciences
Bolling Air Force Base
Washington, D.C. 20332

Table of Contents

1. Accomplishments under AFOSR Grant 78-3608 for the period

1 July 1978 to 30 June 1979

1.1 Papers and Lectures

a. Curved Space Scattering.

i. Invited paper presented at Conference on Mathematical Methods and Applications of Scattering Theory, 21-25 May 1979

ii. to be published by Springer-Verlag.

1.2 Research Objectivities which have been Accomplished.

During the time of the present grant, all mathematical machinery and computer codes necessary to determine the ionospheric structure via the exact fall wave theory have been developed and tested on synthetic models. Some of this work is described below.

Accurate time delay and phase shift data is obtainable with presently available ionosonds. To obtain the reflection coefficient $b(k)$ from the phase $\varphi(k)$ we used the analytic properties of $b(k)$ and developed a generalized form of the Hilbert transform which allows the amplitude $\mathrm{Re}[\ln(b(k))] = \ln|b(k)| = w(k)$ to be calculated from the phase via the relation

$$\ln|b(k)| = \frac{p}{\pi} \int_{-\infty}^{\infty} \frac{k(\varphi(k') - 2z_0 k')\,dk'}{k'(k'-k)} \quad .$$

Here p indicates a principle value and z_0 is the height above the ionosphere to the bottom of the ionosphere. It was necessary to develop this generalized version of the transform because of the particular analytical properties of $b(k)$. The complete reflection coefficient follows via $b(k) = \exp[\ln|b(k)| + i\varphi(k)]$.

The transform was verified analytically for particular cases. For any analytic function $f(z) = R(z)\, e^{i(\varphi(z) + \alpha z)}$ we showed that the amplitude follows via

$$\ln R(z) = \ln R(0) + \frac{p}{\pi} \int_{-\infty}^{\infty} \frac{z[\varphi(z') - \alpha z]\,dz}{z'(z'-z)} \quad .$$

For ionospheric scattering, $R(0) = 1$ and thus $\ln R(0)$ vanishes.

For this transform, a computer program (which takes into account the singular structure of the integrand) was developed and tested on various analytic synthetic scattering data where exact results are known. Below the computed amplitude and phase results for one and two δ-function potentials is compared with the known analytic results. The accuracy of the computer calculation can be set in advance by choosing a parameter. Although any desired accuracy can be obtained subject only to computer precision chosen, six place accuracy was used for the synthetic example. As can be seen from the printout, the precision is greater than six-places in all cases. The reason for such accuracy is that when real data is used, all errors will be due to inaccuracies in the data. Furthermore, computer codes for (1) the Gelfand-Levitan integral equation and (2) a fast Fourier transform have been developed, coded, debugged, tested against synthetic models and found to work well. Initially, noise will be filtered from the data by taking a running average of various numbers of experimental data values. If desirable, more complicated filtering methods for noise reduction will be instituted later. Thus all necessary computer codes are debugged and available for immediate use as soon as the ionosond data becomes available.

Besides this, a manuscript describing our method has been

prepared. This manuscript by Cohen and Moses which is a more detailed version of Section I of this proposal, will be submitted shortly. Also both Cohen and H. E. Moses have presented invited papers at the conference on scattering sponsored by NRL and held in May, 1979.

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SCATTERING FROM 2 DELTA FUNCTIONS.COMPARISON OF VALUES OF LOG(AMPLITUDE) VIA INTEGRAL TRANSFORM (NUMERICAL) OR VIA EXACT ANALYTIC RESULT

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1.3 Interaction with Other Investigators

a. We have participated in the Inverse Scattering Seminar at the Courant Institute of Mathematical Sciences organized by Prof. Peter Lax.

b. We have discussed informally problems of mutual interest concerning inverse scattering theory with Professors Peter Lax, Percy Deift, Louis Nirinberg, and Trubowitz at the Courant Institute. Extensive interaction between the members of the research group has taken place including direct and telephone conversation between the Penn and Lowell contingents.